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VOICE CHANNEL ADDITION TO DIGITAL AUDIO TAPE

BY ARTHUR DELAGRANGE

UNDERWATER SYSTEMS DEPARTMENT

1 APRIL 1992

NAVAL SURFACE WARFARE CENTER
DAHLGREN DIVISION WHITE OAK DETACHMENT
Silver Spring, Maryland 20903-5000

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FOREWORD

This report describes an encoding scheme for adding a voice commentary to a multiplexed DIFAR signal being recorded on Digital Audio Tape (DAT). Theory, circuitry, and performance are given. It may be of interest to persons involved with DIFAR, or those using DAT for other purposes.

Approved by:

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Deputy Department Head
Underwater Systems Department

ABSTRACT

The newly available consumer Digital Audio Tape recorders (DATs) have adequate fidelity to record multiplexed DIFAR signals, replacing instrumentation tape recorders which are considerably larger and more expensive. This report describes a system for adding voice commentary on the same tape channel. The concept could have other applications.

CONTENTS

ILLUSTRATIONS

INTRODUCTION

Multiplexed DIFAR Signals previously were recorded on instrumentation tape recorders. These are rather large and expensive. It has been determined that the signals can successfully be recorded on the new consumer Digital Audio Tape recorders (DATs). These are considerably cheaper and smaller. It was desired to add a voice commentary to each channel rather than waste the entire second channel for voice. This is just barely possible, as explained in the next section.

SYSTEM DESCRIPTION

The frequency spectrum of the composite spectrum recorded is shown in Figure 1. The DIFAR signals extend up to 17.5 kHz, and there is actually noise present up to about 20 kHz due to the finite slope of the filters. The DAT samples at 48 kHz (the 44 kHz option is not high enough), giving a Nyquist limit of 24 kHz; any frequency above this "aliases" (folds) down to an equal amount below 24 kHz. Actually, the response of the DAT is made to fall sharply above 23 kHz to avoid this. Also, the DIFAR subcarrier at 7.5 kHz is generated as a square wave and has a significant harmonic at 22.5 kHz. Therefore, the voice signal had to be modulated at 22.5 kHz to avoid a tone in the audio output from this subcarrier, and the lower sideband only retained. Minimum voice bandwidth for reasonable speech seems to be about 300 Hz to 2 kHz. Again, due to the finite slope of a reasonable filter, energy is present up to about 2.5 kHz. As show in Figure 1, the lower sideband just fits in. The upper sideband is eliminated by Single Side Band (SSB) techniques.

A block diagram of the system is shown in Figure 2. The microphone signal is amplified with a 300-Hz high-pass filter/amplifier having considerable gain. Frequency components above 2 kHz are removed by a sharp low-pass filter having some additional gain. Two versions of the signal phase-shifted by 90 degrees are created by a phase-shift network. A quadrature modulator driven from quadrature phases of a crystal oscillator shifts them up to 22.5 kHz. The upper sidebands cancel when they are summed, while the lower sidebands reinforce. The DIFAR signal is also added in at this point, and the composite signal recorded.

Demodulation is simpler. A single demodulator driven from another 22.5-kHz crystal oscillator shifts the voice spectrum down to baseband (original frequency). A frequency difference between the two oscillators shifts the audio spectrum somewhat, but anything less than 100 Hz is not noticeable. Everything else in the spectrum at this point is well above 2.5 kHz and is removed by another 2-kHz low-pass filter. An amplifier drives a speaker or headphones.

MODULATOR CIRCUITRY

A Radio Shack model 33-984 dynamic microphone is used. The 300-Hz high-pass filter (Figure 3) is a 4-pole Butterworth. Frequency response is shown in Figure 4. Sharp cutoff is not necessary, as 60-Hz hum is probably the main interference and the phase shift network works partially below 300 Hz anyway. Two 2-pole stages are required; a gain of 35 dB can easily be built into it, as the frequency is not high for the operational amplifiers (op-amps).

The-2 kHz low-pass filter (Figure 5) is a 5-pole, 4-zero 1.25-dB/39-dB elliptic design.[1] It must be steep as the different bands are close. Frequency response is shown in Figure 6. The reject band actually starts 15 percent past the cutoff, but a few percent must be added in for cutoff frequency tolerance. 1.25-dB ripple is tolerable for speech. A -39 dB stopband is probably not detectable as speech overlap onto the DIFAR signal or as aliasing back into the speech band. Gain is 15 dB.

The 90-degree phase-shift network (Figure 7) consists of two channels of two 1-pole, 1-zero shifters each in tandem. Each stage is adjusted to give 90 degrees phase shift through it at the frequency indicated. Overall phase difference between the two channels is 90 degrees within 0.5 degree across the 300-Hz-to-2-kHz band, as shown in Figure 8. Overall phase shift and linearity are not relevant in speech.

The modulators (Figure 9) are a common type. They have current outputs, so the two simply share a common load resistor for addition. The DIFAR signal is added in through another resistor. A high-speed follower buffers the output; any distortion here would corrupt the DIFAR signal. A capacitor on the modulator output gives a single-pole low-pass to prevent slew-rate limiting in the output buffer.

The crystal oscillator (Figure 10) runs at 4 times the desired frequency. A divide-by-four then gives precise quadrature phases. Figure 11 shows the actual modulator output spectrum with a 1-kHz tone simulating the voice input, which appears at 21.5 kHz. The carrier feedthrough is at 22.5 kHz and is about 40 dB down. The upper sideband feedthrough, caused by gain difference between the two modulators and phase shifter error, is at 23.5 kHz and is also about 40 dB down. Note also the residual 1 kHz feedthrough, due to imbalance of the modulators, about 50 dB down.

Figure 12 shows the DIFAR spectrum added. Broadband noise was fed to the OMNI and one dipole input. A wideband (5 kHz) demultiplexer was used. The actual signals to be used have a bandwidth of about 3.5 kHz (see Figure 13), so band overlap will be less than shown. If maximum-bandwidth, maximum-amplitude signals are used in the future, some "hiss" is audible in the voice channel, but this would probably be tolerable.

[1] Delagrange, Arthur D., "An Active Filter Primer, MOD 2," NSWC TR 87-174, 1 Aug 1988.

DEMODULATOR CIRCUITRY

The demodulator (Figure 14) is similar to one-half of the modulator; in fact, the same board is used. The same oscillator is used for demodulation for convenience although the quadrature phases are not necessary as in the modulator. The 2-kHz low-pass filter is identical to that of the modulator (Figure 5). The output amplifier (Figure 15) uses a power op-amp capable of driving either headphones or a speaker. Gain is 21 dB. It is preceded by a user-adjusted volume control. This should be a log-taper (audio) potentiometer.

Figure 16 shows the layout of components on the printed circuit card. The same card blank serves as either encoder or decoder by omitting the appropriate parts. The only adjustments required in the circuitry are the phase shifter pots previously mentioned.

OPERATION

To record a tape, connect 110 VAC, 47-420 Hz power to the encoder box. Connect the DIFAR signal from a NSWC multiplexer or other source. If another source is used, level should be adjusted so that the subcarrier levels (7.5 and 15 kHz) are about 100 mV RMS each (-20 dBV). Connect "TAPE" output of the encoder to the DAT "line in." Plug in the mike. Hold the mike as close as possible and speak loudly. The system is set for this; it minimizes the amount of background sound also being recorded. Set the record level on the DAT so that the loudest speech does not quite overload the recorder, which would cause distortion, including the DIFAR signal.

To replay a tape, connect the "line out" of the DAT to "TAPE" input of the decoder (Connect 110 VAC, 47-to-420-Hz power to the decoder box). Plug in headphones, stereo or monaural, or a speaker. Adjust the "VOLUME" control to a comfortable listening level. The DIFAR signal is simply "teed" from the DAT; it does not go through the decoder box.

A Sony model TCD-D3 tape recorder was used for the development. The system will probably work with others, but the response outside the audio band may be different and problems could arise.

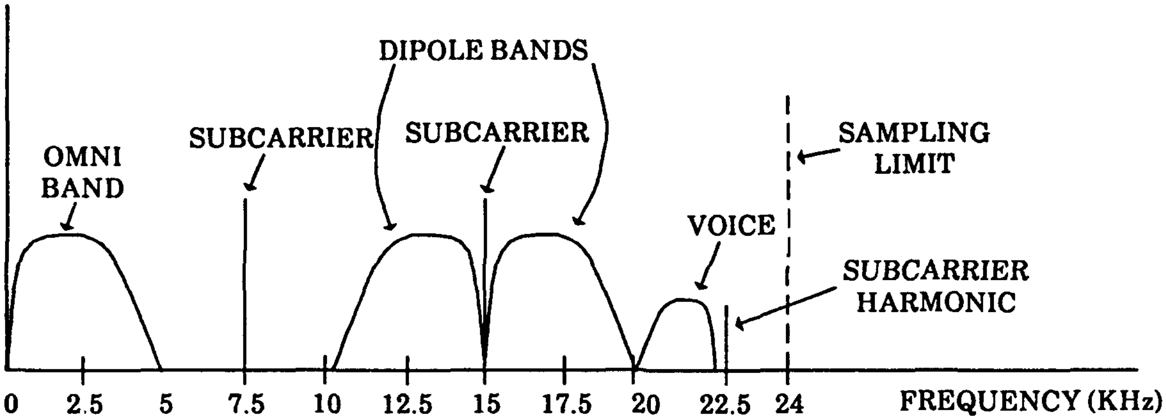


FIGURE 1. FREQUENCY SPECTRUM

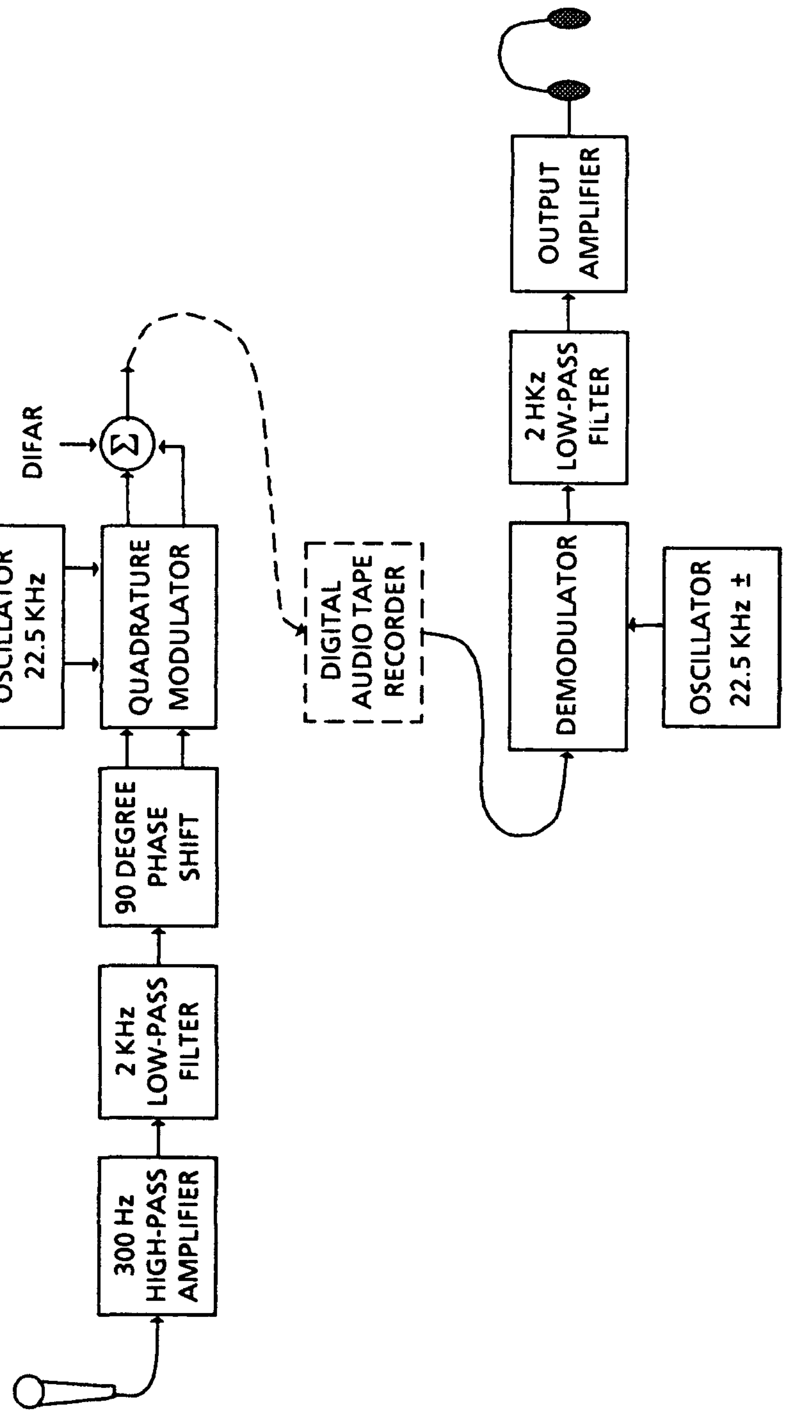
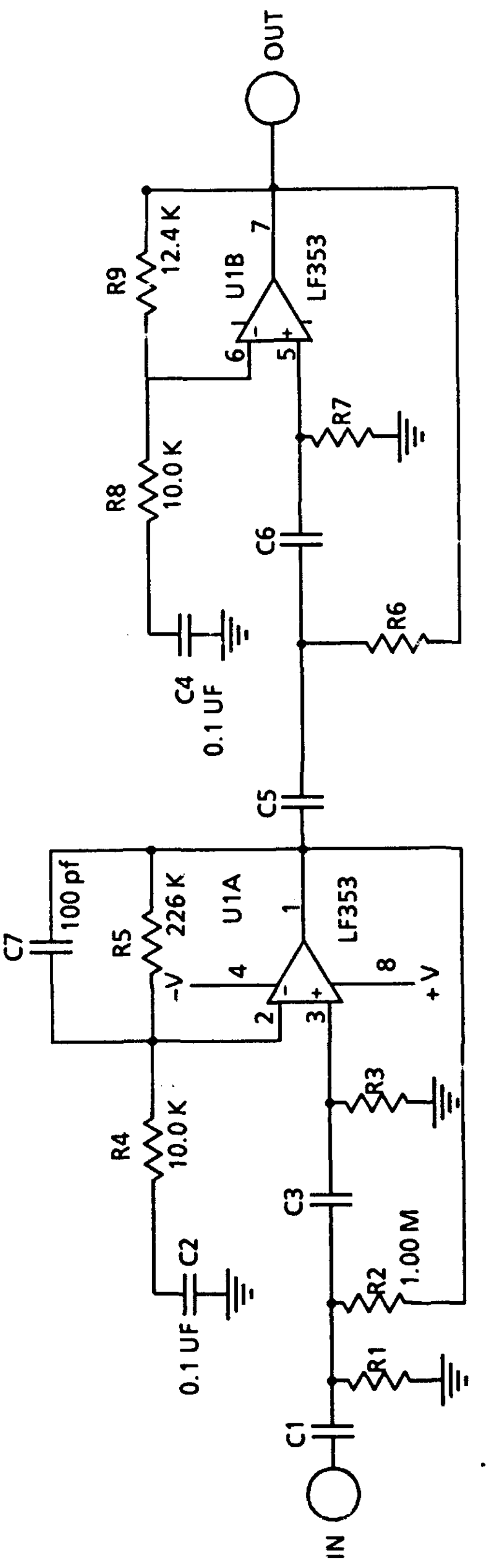


FIGURE 2. BLOCK DIAGRAM—DAT VOICE ADDITION



NOTE: UNMARKED CAPACITORS 0.01 UF 1%
UNMARKED RESISTORS 51.1 K

FIGURE 3. HIGH-PASS AMPLIFIER

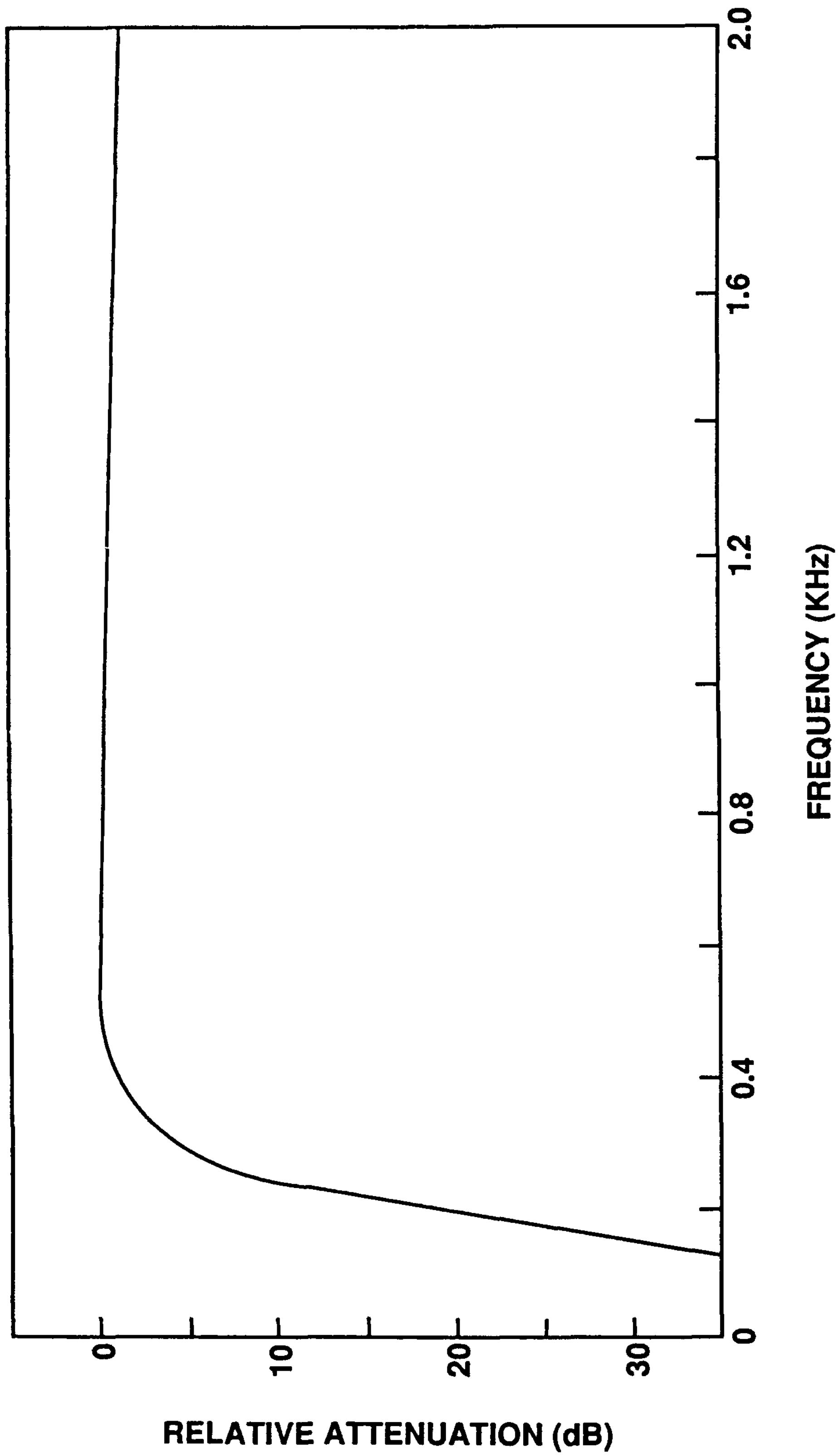
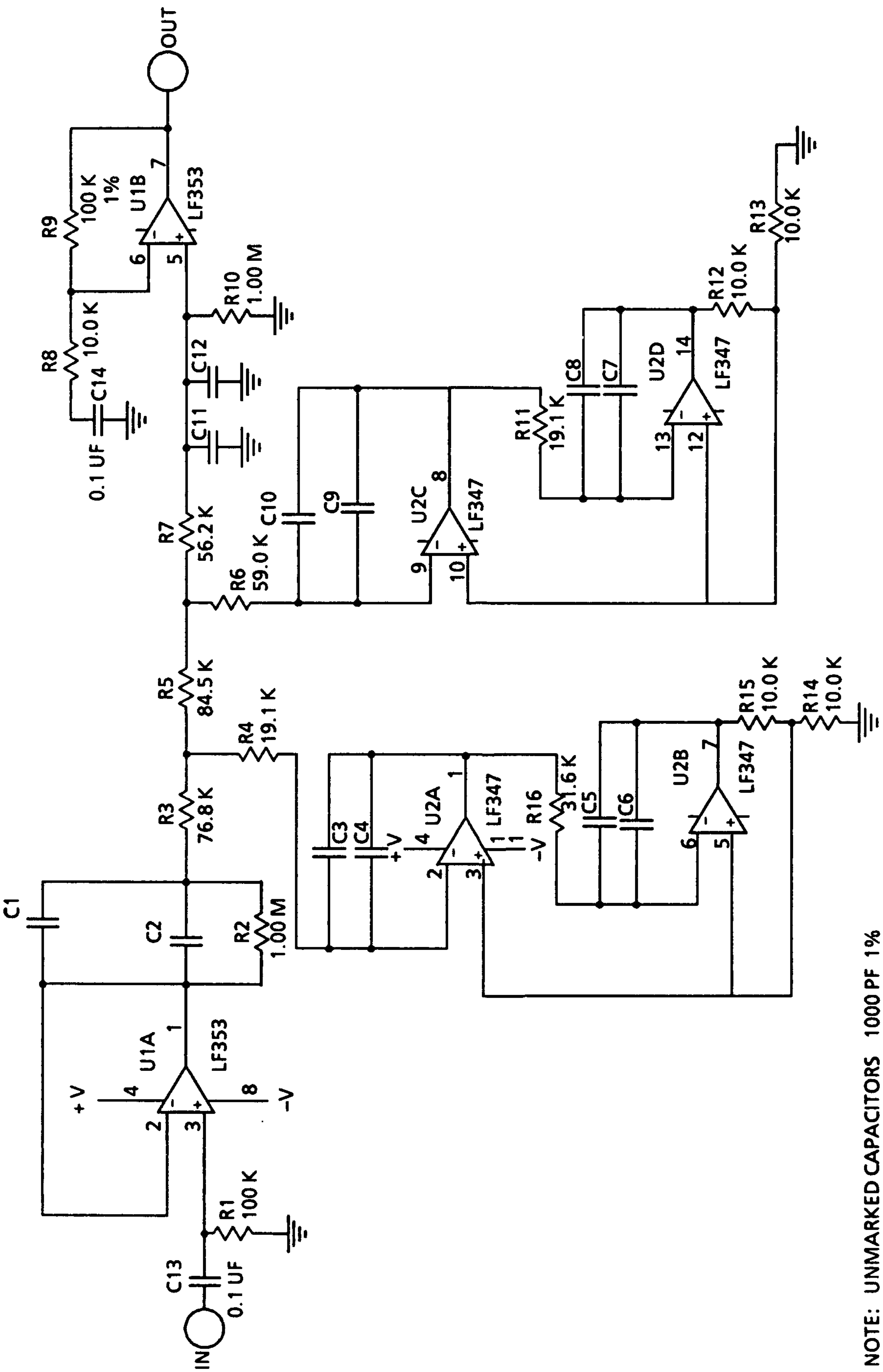


FIGURE 4. HIGH-PASS CHARACTERISTIC



NOTE: UNMARKED CAPACITORS 1000 PF 1%

FIGURE 5. LOW-PASS FILTER

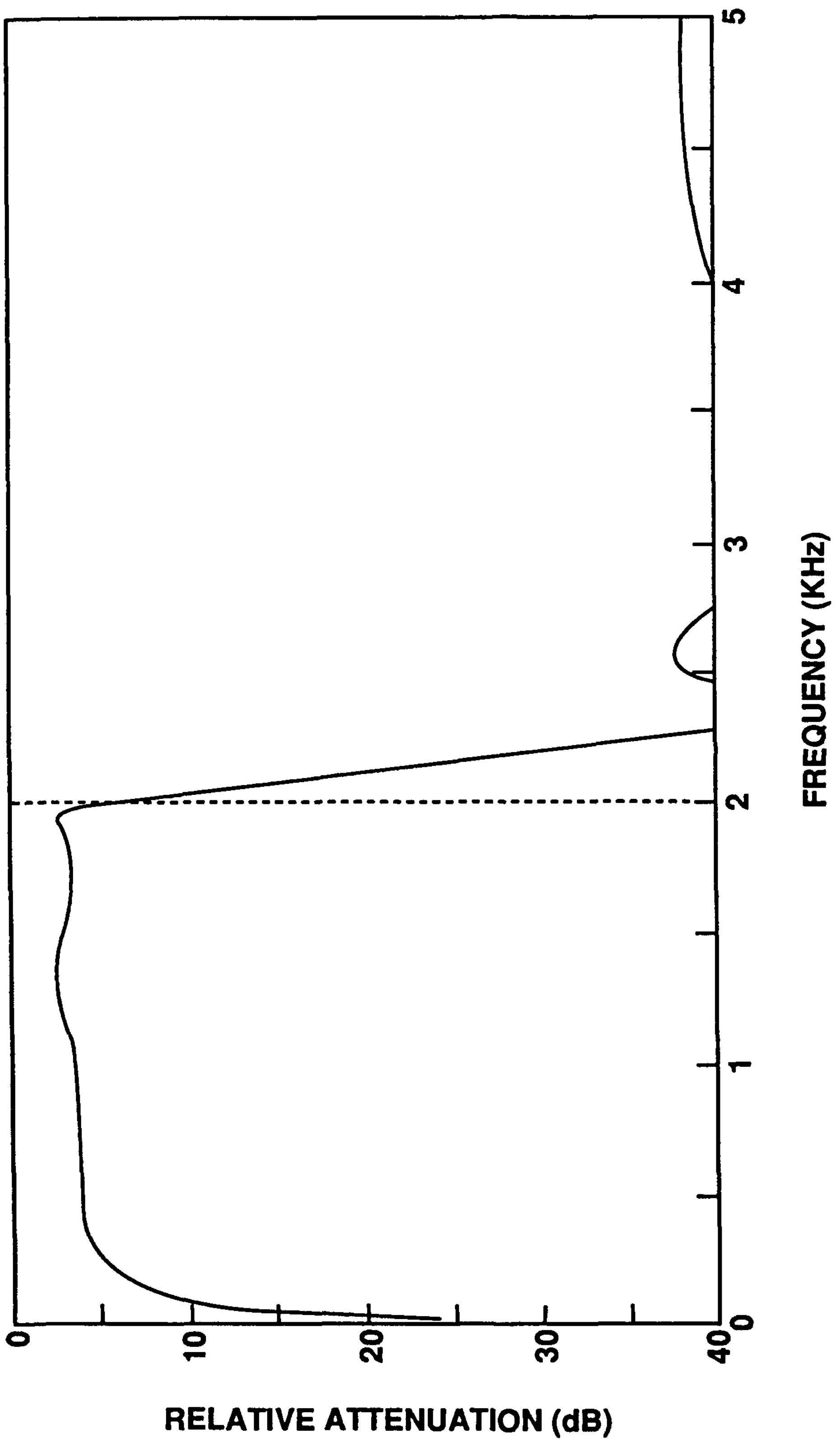


FIGURE 6. LOW-PASS CHARACTERISTIC

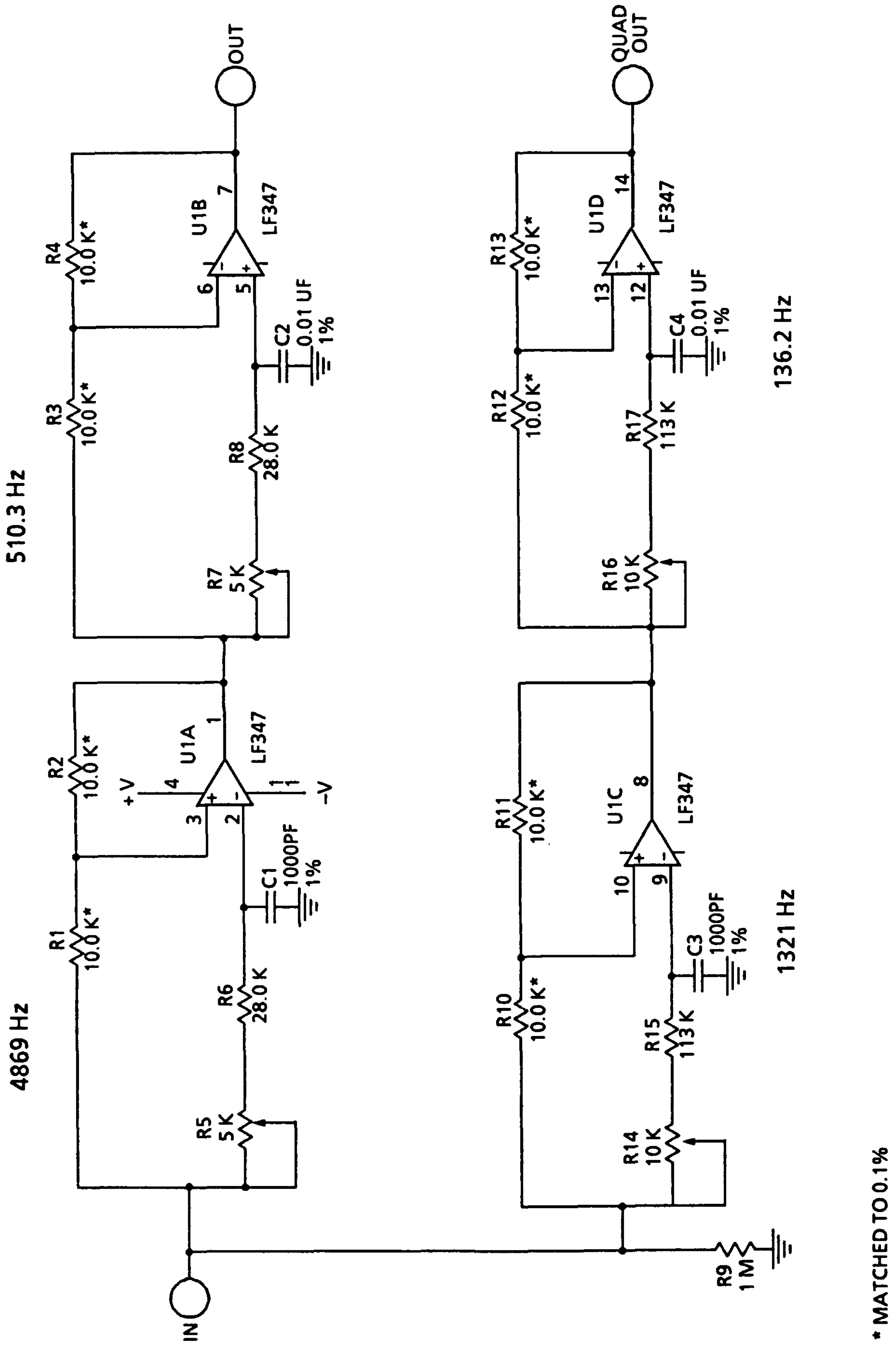


FIGURE 7. PHASE SHIFTER

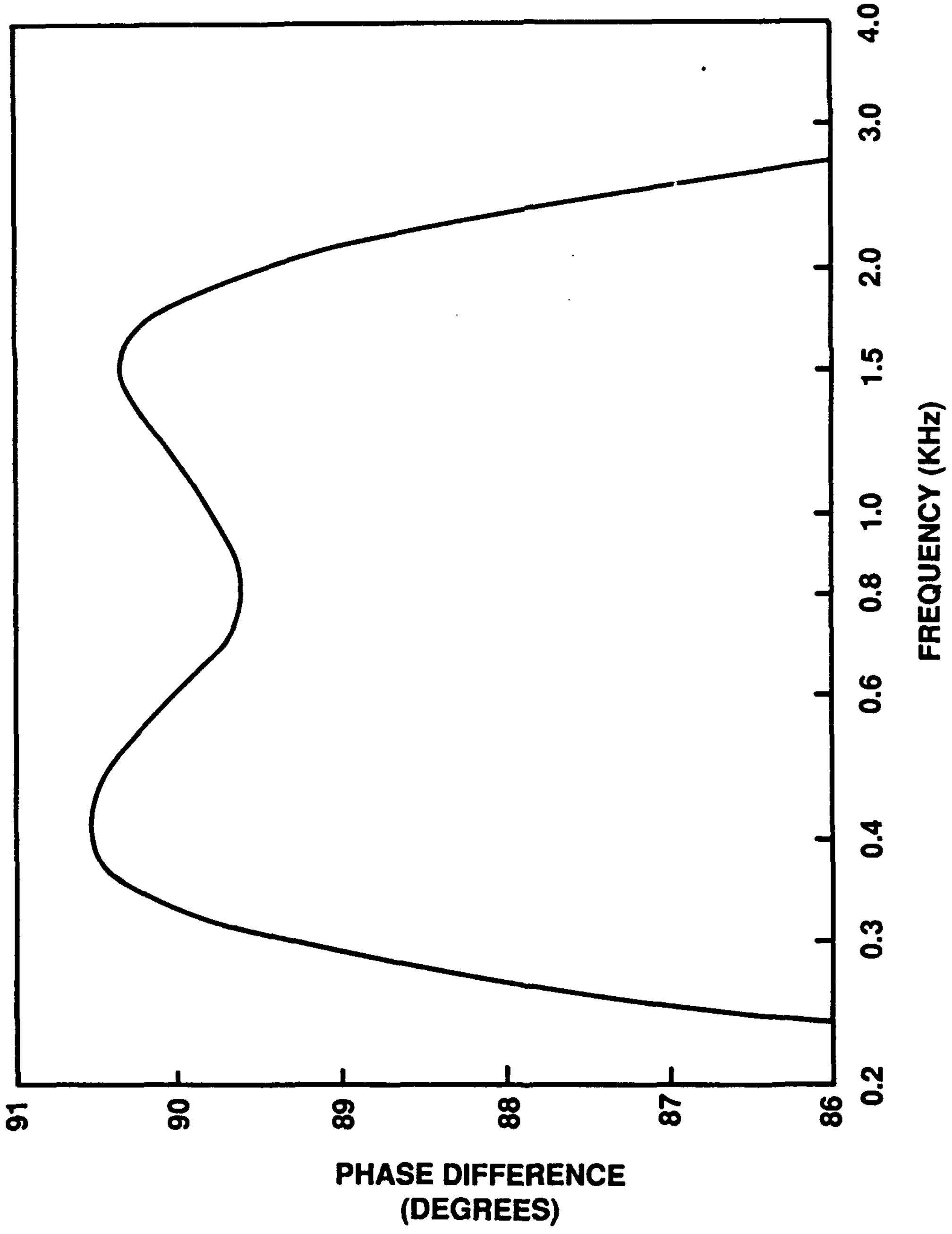


FIGURE 8. PHASE SHIFT NETWORK CHARACTERISTIC

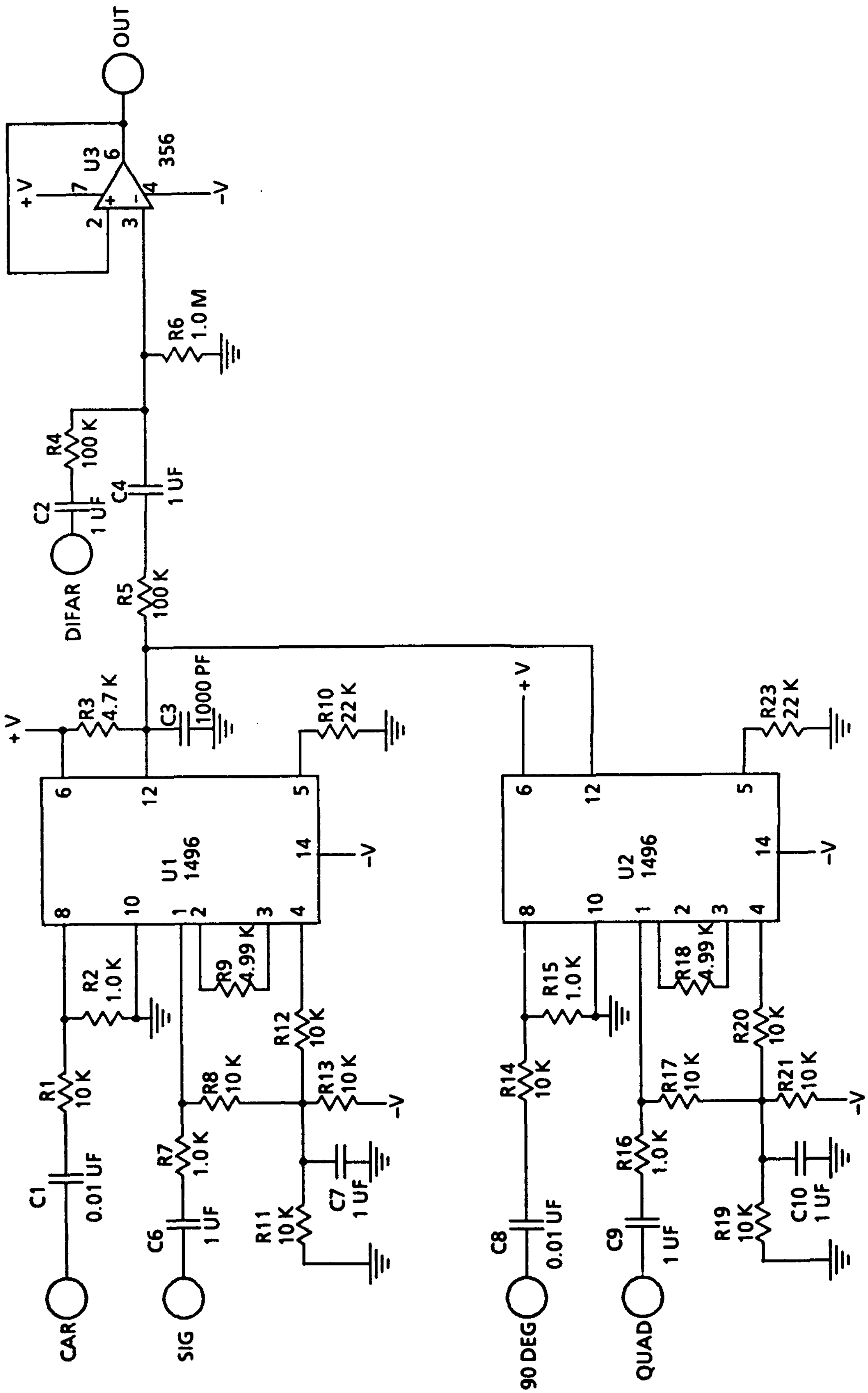


FIGURE 9. MODULATOR

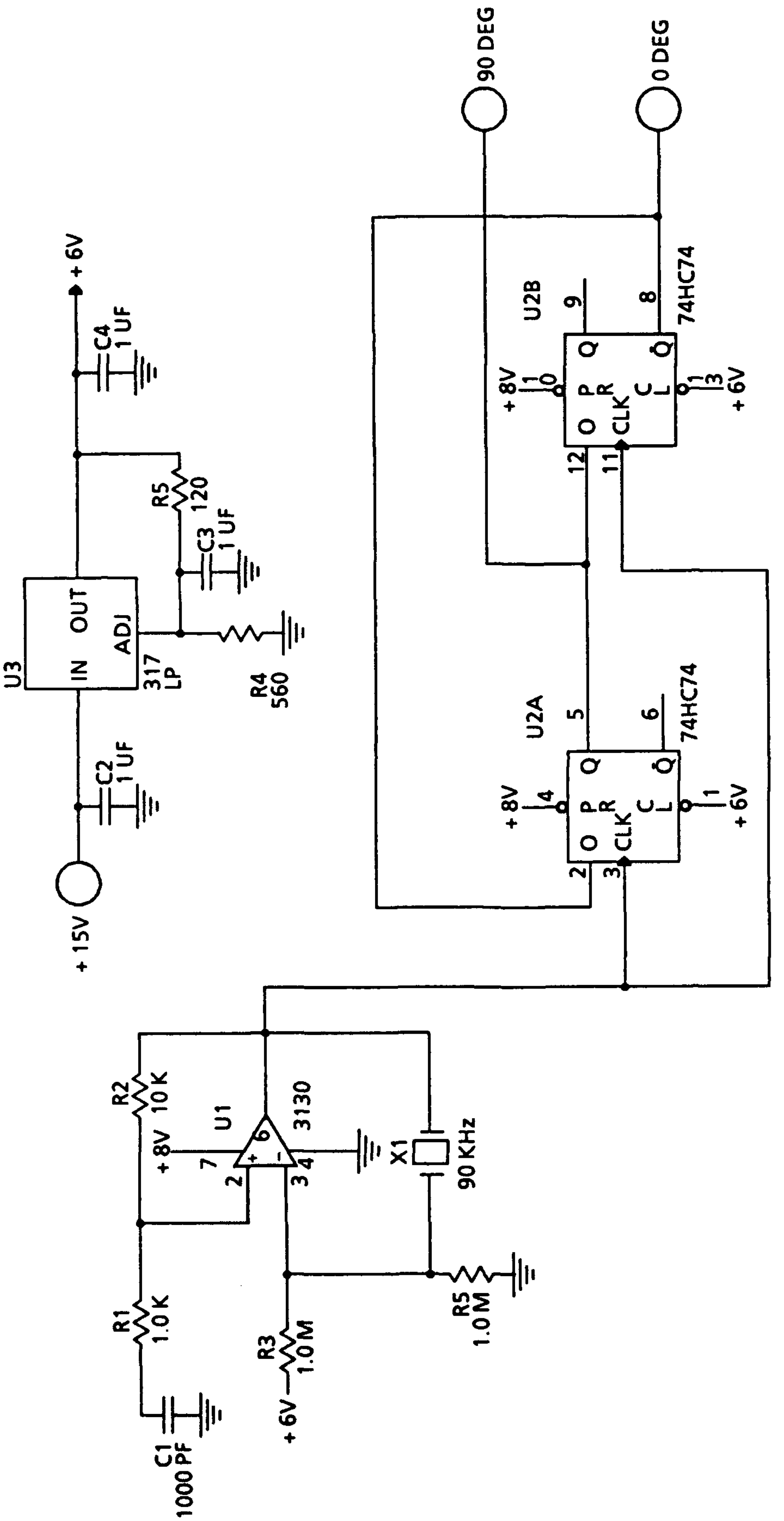


FIGURE 10. OSCILLATOR

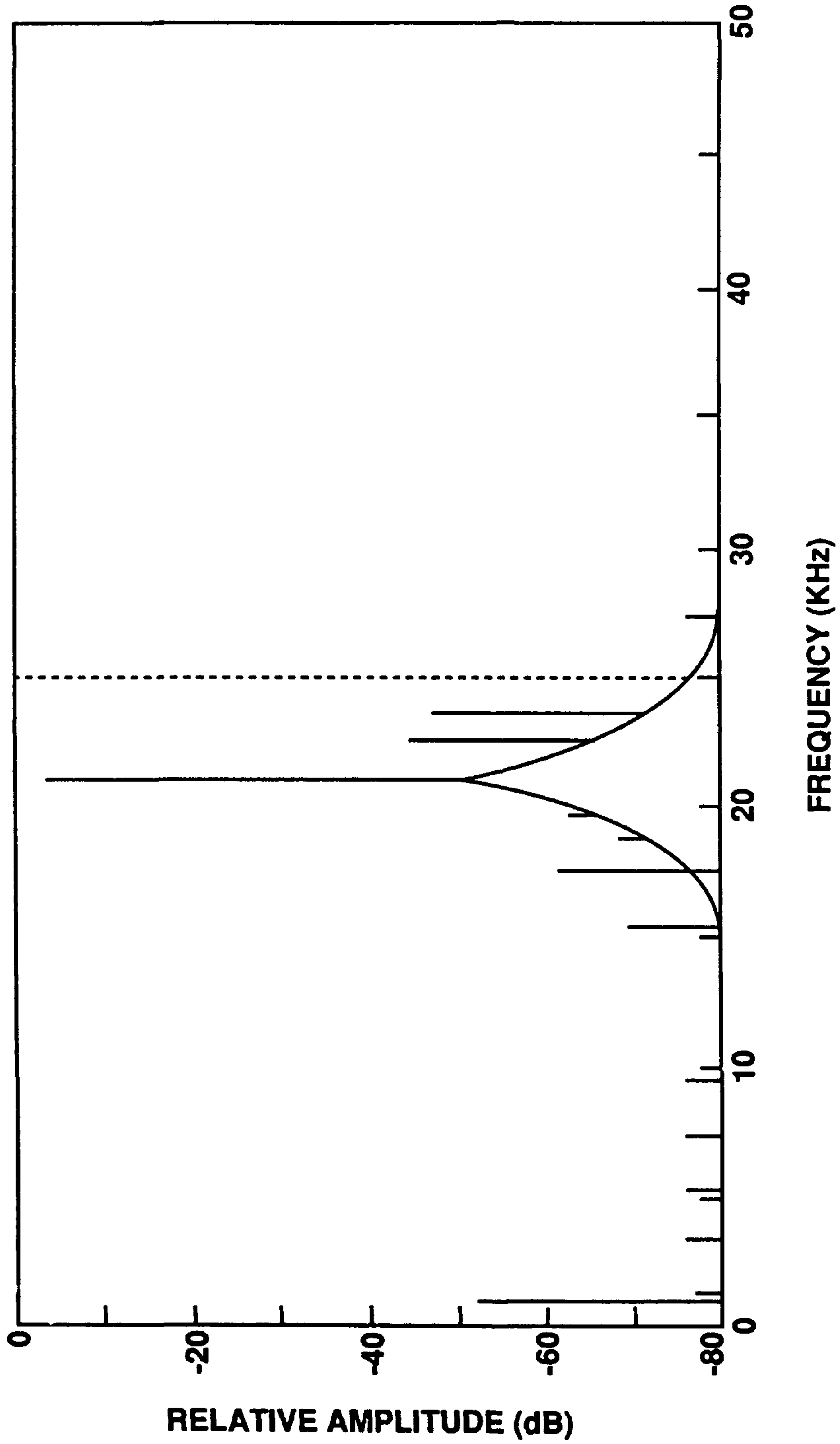


FIGURE 11. OUTPUT SPECTRUM, 1 KHz VOICE TONE

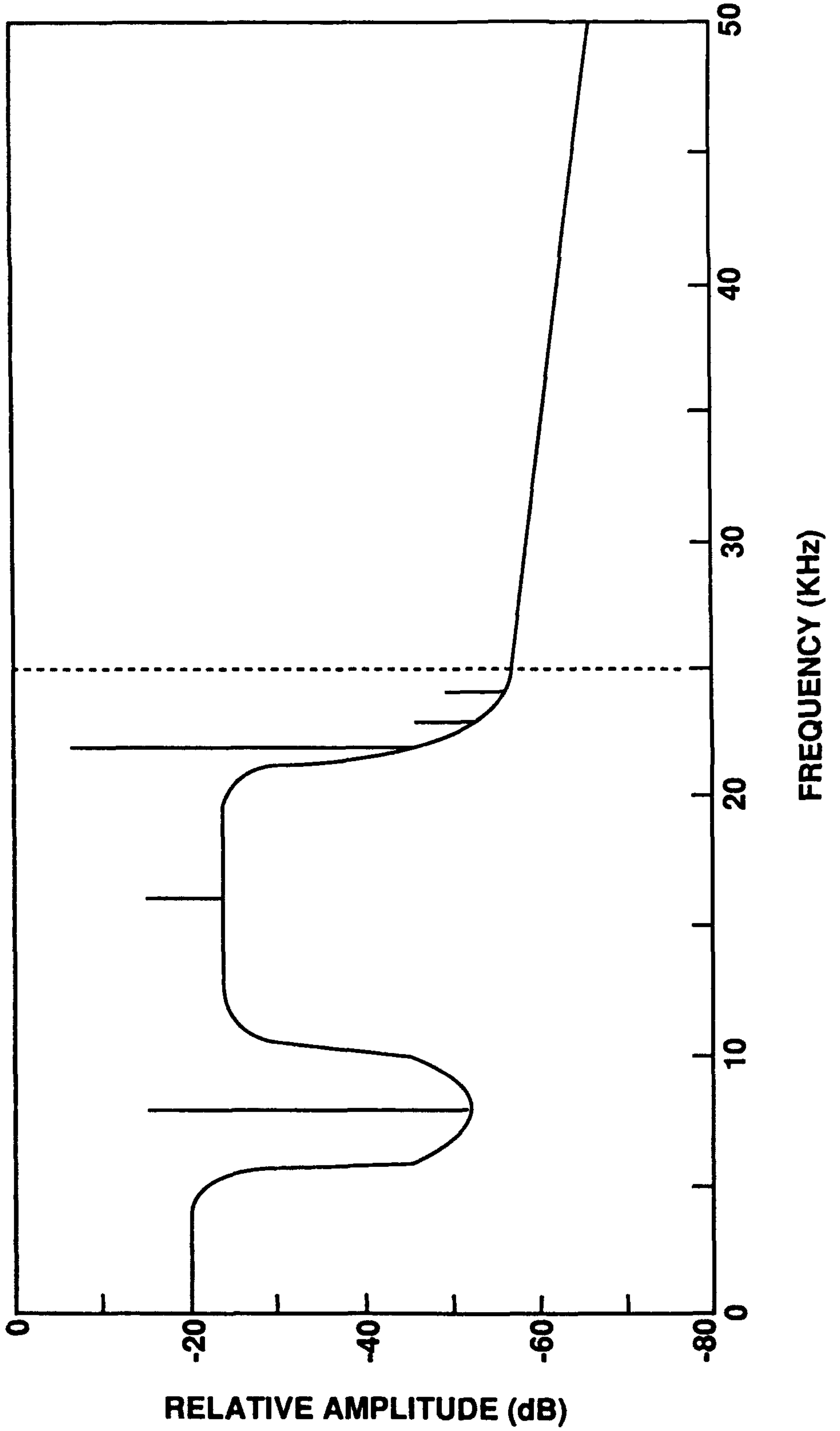


FIGURE 12. OUTPUT SPECTRUM, 1 KHz VOICE TONE AND DIFAR BROADBAND

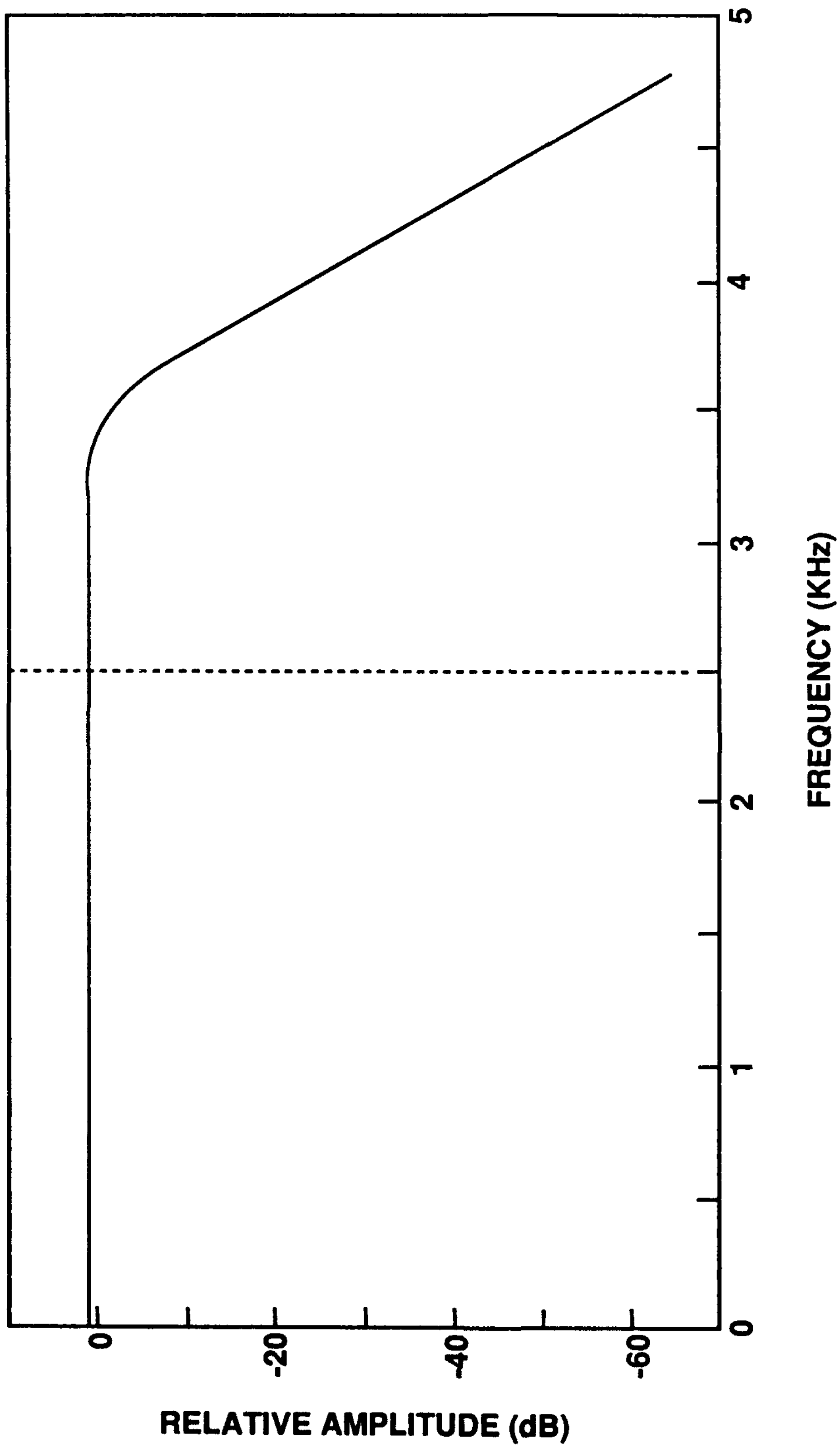


FIGURE 13. SPECTRUM OF DIFAR SIGNALS ACTUALLY USED

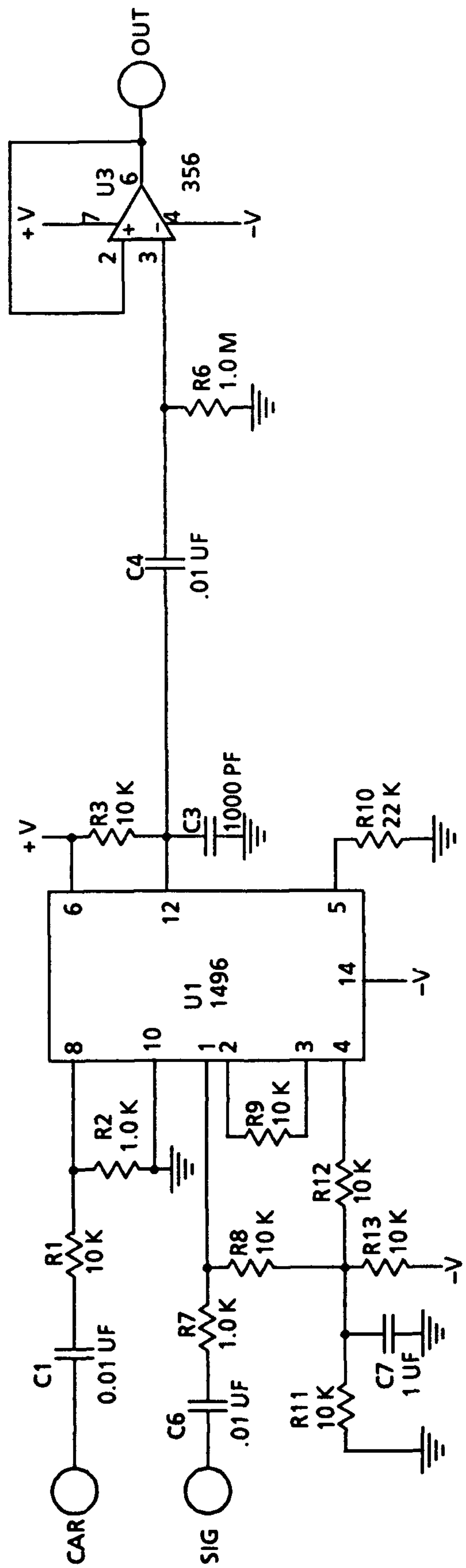


FIGURE 14. DEMODULATOR

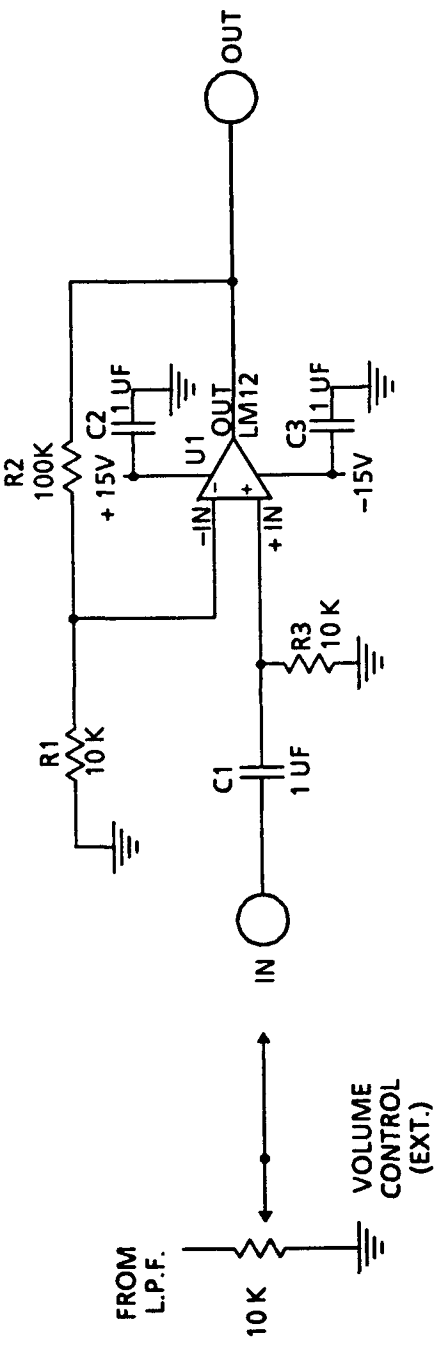


FIGURE 15. OUTPUT AMPLIFIER

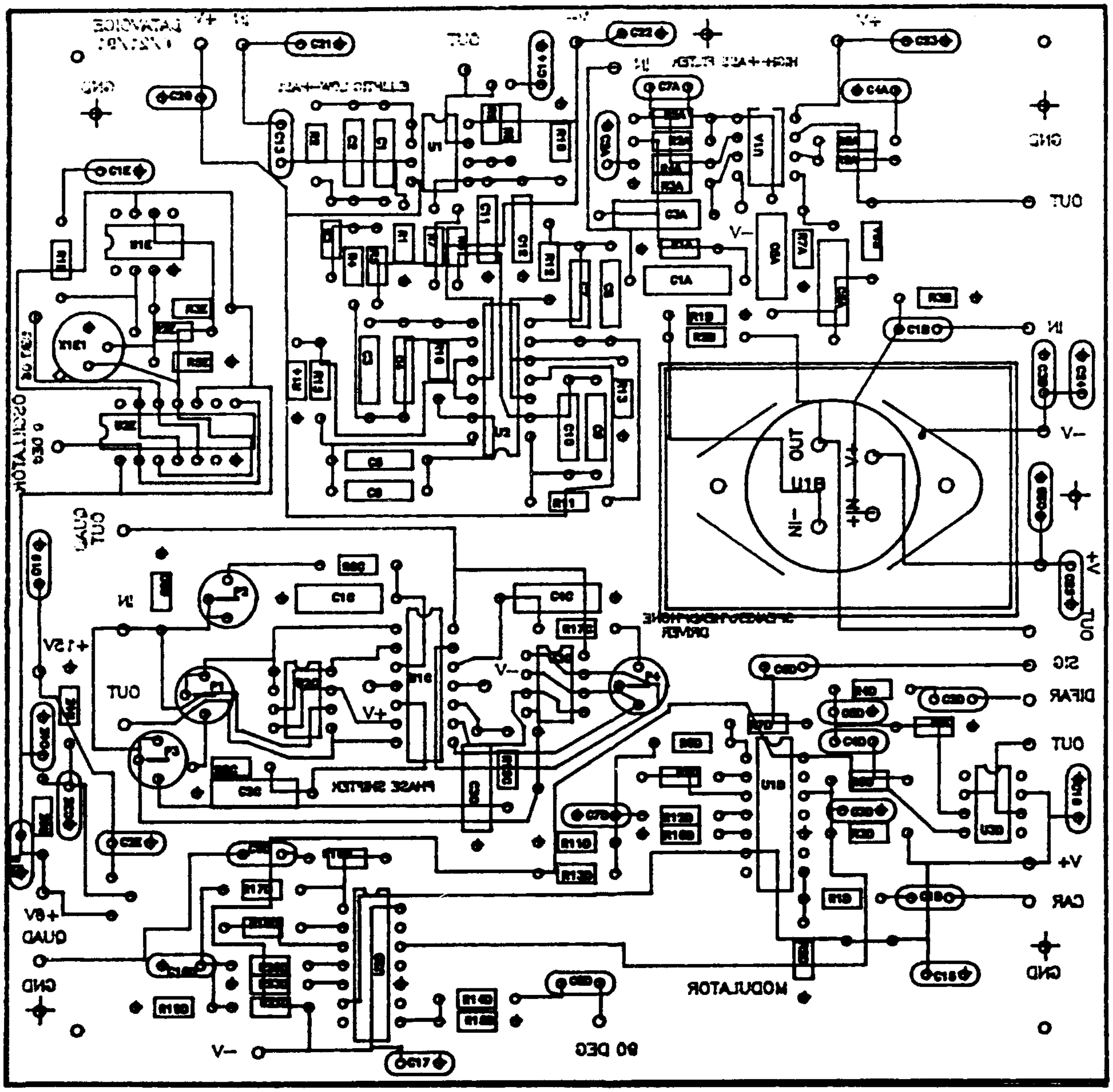


FIGURE 16. PRINTED-CIRCUIT CARD LAYOUT

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13. ABSTRACT *(Maximum 200 words)*

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